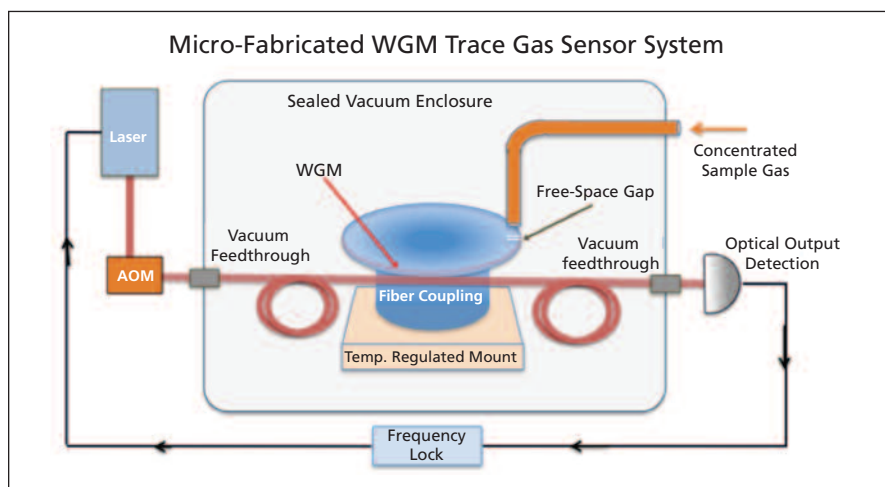




The **Trace Gas Detection System** features a concentrated sample gas flowing to the free-space gap in the microfabricated disc, packaged inside a compact sealed enclosure with external laser and detection electronics. Also shown is a SEM image of a high- Q calcium fluoride disc that has been augmented with a notch using FIB.

optical whispering gallery mode resonators (WGM) with microfabrication technology used in the semiconductor industry. For direct access to the optical mode inside a resonator, material can be precisely milled from its perimeter, creating an open gap within the WGM. Within this open notch, the full optical mode of the resonator can be accessed. While this modification may limit the obtainable Q , calculations show that the re-

duction is not significant enough to outweigh its utility for trace gas detection. The notch can be milled from the high- Q crystalline WGM with a focused ion beam (FIB) instrument with resolution much finer than an optical wavelength, thereby minimizing scattering losses and preserving the optical quality. Initial experimental demonstrations have shown that these opened cavities still support high- Q whispering gallery modes.

This technology could provide ultra-sensitive detection of a variety of molecular species in an extremely compact and robust package. With this type of modified WGM, one can inject a gas sample into the open gap, allowing highly sensitive trace molecule detection within a roughly 1-cm volume. Other critical components of the instrument, such as the detector and a semiconductor laser, could be directly packaged with the resonator so as to not significantly increase the size of the device.

Besides its low mass, volume, and power consumption, the monolithic design makes these resonators intrinsically robust devices, capable of handling significant temperature excursions, without moving parts to wear out or delicate coatings that can be easily damaged. A sensor could integrate with microfluidics technology for a chip-scale device. It could be mounted to the end of a deployable arm, or inserted into a borehole. Also, a network of individual sensors could be dispersed to monitor conditions over a wide region.

This work was done by David C. Aveline, Nan Yu, Robert J. Thompson, and Dmitry V. Strelakof of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-47173

▶ Commercial Non-Dispersive Infrared Spectroscopy Sensors for Sub-Ambient Carbon Dioxide Detection

Lyndon B. Johnson Space Center, Houston, Texas

Carbon dioxide produced through respiration can accumulate rapidly within closed spaces. If not managed, a crew's respiratory rate increases, headaches and hyperventilation occur, vision and hearing are affected, and cognitive abilities decrease. Consequently, development continues on a number of CO₂ removal technologies for human spacecraft and spacesuits. Terrestrially, technology development requires precise performance characterization to qualify promising air revitalization equipment. On-orbit, instrumentation is required to identify and eliminate unsafe conditions. This necessitates accurate *in situ* CO₂ detection.

Recursive compensation algorithms were developed for sub-ambient detection of CO₂ with commercial off-the-shelf (COTS) non-dispersive infrared (NDIR) sensors. In addition, the source of the exponential loss in accuracy is de-

veloped theoretically. The basis of the loss can be explained through thermal, Doppler, and Lorentz broadening effects that arise as a result of the temperature, pressure, and composition of the gas mixture under analysis.

The objective was to develop a mathematical routine to compensate COTS CO₂ sensors relying on NDIR over pressures, temperatures, and compositions far from calibration conditions. The routine relies on a power-law relationship for the pressure dependency of the sensors along with an equivalent pressure to account for the composition dependency. A Newton-Raphson iterative technique solves for actual carbon dioxide concentration based on the reported concentration. Moreover, first principles routines were established to predict mixed-gas spectra based on sensor specifications (e.g.,

optical path length). The first principles model can be used to parametrically optimize sensors or sensor arrays across a wide variety of pressures/temperatures/compositions.

In this work, heuristic scaling arguments were utilized to develop reasonable compensation techniques. Experimental results confirmed this approach and provided evidence that composition broadening significantly alters spectra when pressure is reduced. Consequently, a recursive compensation technique was developed with the Newton-Raphson method, which was subsequently verified through experimentation.

This work was done by Michael J. Swickrath and Molly S. Anderson of Johnson Space Center, Summer McMillin of Jacobs Technology, and Craig Broerman of Hamilton Sundstrand. Further information is contained in a TSP (see page 1). MSC-25343-1